The Comet of 1556; *its possible breaking up by an unknown planet into three parts seen in* 1843, 1880, *and* 1882. By George Forbes, F.R.S.

The writer has never attached undue importance to the speculation advanced by him in 1880 about an unknown planet, but the additional support given to that speculation by the facts now stated, and the greater exactness given to the hypothetical position by using these facts for revising the calculations, seem to call for the present paper. Thus only can observers in the southern hemisphere have an opportunity, if they think fit, of searching for the hypothetical planet, of whose existence, within a few degrees of the place now indicated, the evidence herewith adduced leaves hardly any room for doubt.

1. The comet of 1556 was supposed to be identical with the comet of 1264, and its return about the year 1848 was confidently predicted, and especially by Hind (see *M.N.*, vols. vii., viii., x., also "On the expected return of the great comet of 1264 and 1556," London, 1848; and "The comet of 1556," London, 1857). The identity of the comet of 975 with these was also suspected.

Elements of the orbit of comet 1264 have been computed by Dunthorne, Pingré (two), and Hoek (three). These and all other elements of orbits referred to in this communication are given in Dr. J. G. Galle's *Cometenbahnen*, Leipzig 1894.

Elements of the orbit of comet 1556 have been computed by Halley, Hind (three), and Hoek. These are all deduced from the observations of Fabricius, but the later computers had also access to the far better observations of Joachim Heller.

In the following elements of the orbit of comet 1556, as in other citations in this communication ω is what Galle calls the Argument des Perihels and is the angle from ascending node to perihelion measured in the direction of comet's motion.

Elements of Comet 1556.

Perihel. Passage.	ω.	☊.	i.	Log Perihel. Dist.	Computer.
1556.	° ′ ″	° ′ ″	° ′ ″		
Apr. 21·842	103 8	175 42	32 6 30	9·666424	Halley.
Apr. 21·8077	91 3 54	176 33 48	36 11 24	9·75246	Hind.
Apr. 21·0037	86 20 0	176 29 6	36 39 12	9·78254	*idem.*
Apr. 22·0298	98 49·1	175 25·8	30 12·2	9·70323	*idem.*
Apr. 22·1911	100 52·6	175 13·9	32 25·7	9·69092	Hoek.

[Mean Equinox, 1556·0.]

Now, if the non-appearance of the comet in 1848 as expected was due to a complete change in its orbit by the perturbations of an unknown planet, it is certain that this would be most likely to

happen at or about its aphelion position, which in normal conditions it would reach in the year 1702 A.D.

The longitudes (L) and latitudes (λ) of aphelion and L′, λ′ of a point on the orbit 2° in advance of aphelion deduced from the elements above are—

L.	L′.	λ.	λ′.	Computer.	
° ′	° ′	° ′	° ′		
106 11	108 27	−31 10	−30 52	Halley	M.E. 1908·0.
92 58		−36 11		Hind I	
87 0		−36 34		Hind II	
100 36	102 59	−29 48	−29 37	Hind III	
103 9	105 29	−31 46	−31 31	Hoek	

2. The comets 1843 I., 1880 I., and 1882 II. have been long recognised as a group because of the resemblance in their orbits. These are certainly not identical; but they all have retrograde motion, and they all approach very close to the Sun's surface at perihelion, and the other elements are not very different, as shown below.

Computer.	Perihelion Passage.	ω.	☊.	*i*.	Log. *q*.	Excentricity.
		° ′ ″	° ′ ″	° ′ ″		
Hubbard	1843, Feb. 27·41702	82 34 38	1 14 55	144 19 21	7·7433765	0·99991572
Kreutz	1880, Jan. 27·62502	86 18 7	6 10 29	144 39 42	7·739478	
Kreutz	1882, Sept. 17·23051	69 34 35	346 0 43	141 59 45	7·8889895	0·9999330

In each case the last orbit quoted by Gallé has been adopted as being the best. In the case of comet 1843 I., there are 18 orbits in Galle, and some of the orbits first computed differed sensibly, but the later ones not much, and Hubbard's work is generally recognised as the best. In the case of comet 1880 I., there are 10 orbits in Galle, all agreeing pretty well; Gould's orbit is almost identical with that of Kreutz, and Hind's is very similar. In the case of comet 1882 II., there are 34 orbits in Galle, all agreeing fairly well together.

The point of similarity between the orbits of these three comets to which attention is now to be directed is the following:—

The position of aphelion of each comet is in the same part of the heavens. The following table gives the longitude and latitude of the aphelia, (L and λ), and also of a point further advanced on the orbit by 2° (L′ and λ′), to show the plane of motion.

Comet.	L.	λ.	L′.	λ′.
	° ′	° ′	° ′	° ′
1843 I.,	101 17	−35 35	98 51	−35 30
1880 I.,	101 6	−35 14	98 39	−35 19
1882 II.,	101 40	−35 13	99 18	−35 44
	Aphelion.		2° in advance of Aphelion.	
Mean	101 21	−35 21	Mean Equinox 1908·0.	

These three aphelion positions are practically identical.

No attention, so far, has been paid to the aphelion distances deduced from any elliptic orbits that have been assigned to these comets. But the identity of the aphelion directions coupled with the variation in other elements leads to the inevitable conclusions that :—

These three comets have elliptic orbits.

They were one body when last in aphelion, and then separated in slightly different orbits.

On comparing the aphelion directions of comet 1556, and recognising the degree of uncertainty attaching to them, the conclusion is almost irresistible that the lost comet 1556, when at aphelion, was disturbed by an unknown planet and broken up into at least three parts.

Acting upon this supposition, it is easy to supply very nearly the one uncertain element of these three comets.

Taking 292 years, from 1264 to 1556, as the period of that comet, its mean distance is 44·01; and, from the perihelion distance given by Hoek, the aphelion distance of comet 1556 is 87·52. This may be taken also as very nearly the aphelion distance reached by the three comets 1843 I., 1880 I., 1882 II., at or about the date A.D. 1702.

It may be well here to note the aphelion velocities :—comet 1556, $v = +{\cdot}07072$; comet 1843 I., $v = -{\cdot}00753$; comet 1880 I., $v = -{\cdot}00742$; comet 1882 II., $v = -{\cdot}00891$.

Since these motions are all nearly parallel to the ecliptic, it may be noted that the velocity to be given by the unknown planet to comet 1556, to transform its orbit into one of the others, is nearly the same in each case, and is less than $-{\cdot}08 = 0{\cdot}24$ miles per second. As before, the unit velocity is one Earth's distance from the Sun in one year.

3. An unknown planet, whose existence was suspected, at a distance from the Sun equal to about 100 times the Earth's distance, had a hypothetical orbit and position in that orbit assigned to it by the writer in 1880.* That distance was assigned from the fact that seven comets appeared to have their aphelia at about that distance, and from the analogy of comets whose aphelia are similarly associated with Jupiter and Neptune. An orbit was assigned by noticing that four of these aphelion positions seemed to lie on one plane passing through the Sun; and a position in that orbit was assigned by comparing the mean motion of a planet at such a distance with the dates when the comets reached their aphelia.

From these data the orbit was defined as follows: "The longitude of its ascending node is at 250°, and it cuts the ecliptic at an angle of 53°." As to the position of the planet in its orbit the following statements were made: "comet IV. was influenced by the planet in the year 409 A.D.; comet II. in 1655. The interval is 1246 years. The longitude of aphelion of comet IV. [measured on the above orbit] is 29°. That of comet II. is 115°,

* See *The Observatory*, June 1880. Also *Proc. R.S.E.*

which added to 360° gives 475°. The difference is 446°, which is accomplished in 1246 years, which gives 2·794 years to 1°; and a complete revolution in 1006 years, agreeing remarkably with the period determined from the assumed distance of the planet."

Then again: "Returning now to the hypothetical planet, if we wish to determine the present position (A.D. 1880) of the planet. The mean of the four dates of aphelion disturbance by the hypothetical planet is the year 1160 A.D., and the mean longitude of the planet at these four times is 287°. From the year 1160 to 1880 it must have passed over 258°, whence its present position in its orbit (A.D. 1880) is in longitude 185°."

From the above data the hypothetical planet in 1702 would be in longitude 106° 59′ and latitude $-38°$ 33′; and after covering two degrees further in its orbit (in about 1708) its position would be longitude 108° 55′; latitude $-39°$ 49′.

This is quite near the aphelion positions of comets 1556, 1843 I., 1880 I., and 1882 II. Producing backwards the supposed path of the planet, the proxmity is at first startling.

The coincidence loses, however, some of its apparent importance when it is remarked that such proximity was to be expected from the fact that the comet 1843 I. was one of those whose aphelion positions were found to lie on one plane through the Sun at about the same distance. On the other hand, this fact makes the chances of finding the planet greater.

4. By inspection of the accompanying chart, the three coincidences to which attention has been drawn are made very clear.

By far the most important of these is the second. That three distinctly different orbits of comets should all intersect at one point is almost a certain proof that these were at that point broken up from a single comet, either by explosion or by the influence of a planet in close proximity.

The latter explanation is rendered more probable when we remember that Lexell's comet thus twice approached Jupiter so closely as to have its orbit completely changed.

The probability of this explanation is increased by the fact that the point of assumed disturbance was at the comets' aphelia, where the slow motion gives a planet the best chance of disturbing the orbit. It was at aphelion that Lexell's comet was disturbed.

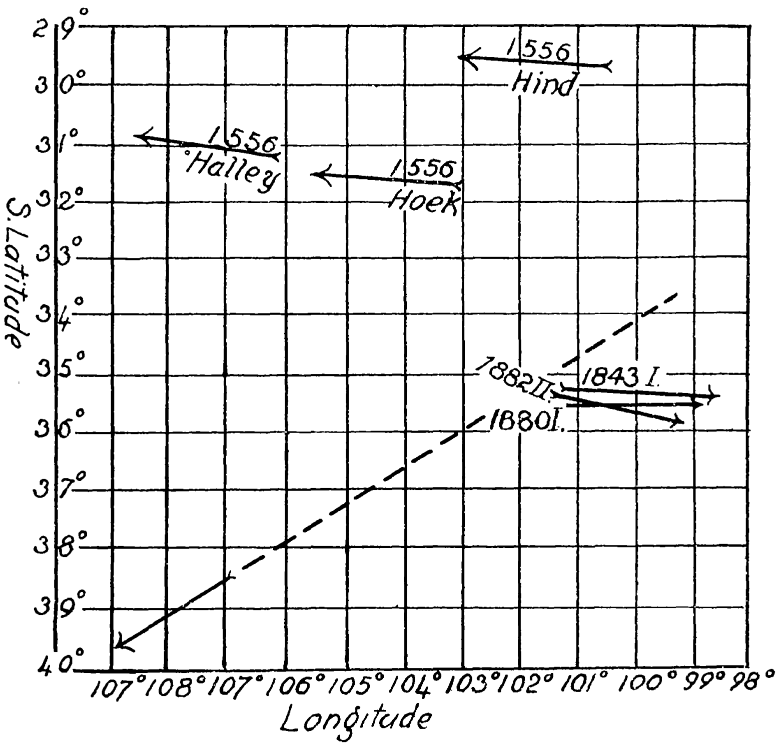
The non-agreement of calculated aphelion distances of these three comets counts for nothing, because all of them had such extremely small perihelion distances. In such a case it is impossible to arrive with any certainty either at the period or at the aphelion distance by calculation from the observations.

The evidence that the comet which was thus broken up was the comet of 1556 is threefold:—(1) the non-appearance of that comet about 1848 as expected; (2) the good agreement of the dates of appearance of all three comets with the supposition of their having been at or about their aphelia in 1702; (3) the agreement of the directions of aphelia in spite of the difficulties there have been in interpreting the observations of 1556. This last coinci-

dence is the more notable from a search made by me through all the cometary orbits recorded by Galle, and, except comet 1887 I., there is no other that falls within many degrees of the aphelia of the three comets of our group.

The change from direct to retrograde motion is no objection. The total negative velocity given by the disturbing planet to comet 1556, to convert the orbit into that of any of the three, is very small.

If this evidence be accepted, it helps most materially in a search for the planet. The identity of comets 1556 and 1264 gives the period, and thence the aphelion distance 87·52, and the date of aphelion 1702. These are the distance and date likewise for the



supposed planet, while the latitude and longitude of the planet at that date are best given by the far more accurate observations of the three 19th century comets, taking the mean of their aphelia.

Starting with the known position (including radius vector) of the unknown planet at a certain date makes the quest far more promising, and this is a far more useful result than anything attempted in the work on the subject in 1880.

That investigation remains, however, the only guide as to the path of the planet since A.D. 1702 and its mean motion.

A new calculation, with fuller data, has therefore been undertaken; and this was necessitated by the fact that while the mean distance of the planet is 100 or more, its distance from the Sun in 1702 was only 82·52. Assuming this to be the planet's perihelion, we must use an orbit the excentricity of which materially affects

the calculations. The work done in this revision will now be given.

5. Before stating the results of a revision of the work in 1880, it must be mentioned that at that time an alternative position of the planet was given on the supposition that its orbit was near the ecliptic.

The reason was that by this means it had been possible to find the true position of Neptune within three degrees by using the five available comets, some of whose aphelia were not near the ecliptic. Four of these were found to have aphelion dates that fitted the possible motion of a planet. Three out of these four aphelion positions were near the ecliptic. This now seems wrong, and the Neptune group ought to have been taken to support the orbit of the unknown planet not on the ecliptic; in fact, the orbit which explains the apparent disappearance of comet 1556.

It must further be stated that those who have searched for the planet have done so only in the ecliptic position.

The writer must here explain that he would certainly have searched the other place, but shortly after he wrote that paper he devoted himself to assisting to lay the foundations of the profession of electrical engineering, and his time was till lately so absorbed by these duties that he was never free to continue his search for the planet.

6. Revision of the work published in 1880.

This work was based on the discovery that there seemed to be seven comets whose aphelion distances from the Sun were about 100 times the distance of the Earth. This seemed to make it certain, from the analogies of the Jupiter and Neptune groups of comets; and from the work of Professor Newton on the capture of comets, which gave an explanation of that connection between comets' aphelia and planetary distances—that there is an unknown planet at or about the mean distance 100, revolving round the Sun in about 1000 years.

Out of these seven aphelia, four were found to lie almost exactly on a plane passing through the Sun. [An error of computing has been now corrected in this part of the work on comet 1855 II.] It seemed likely that this might be the true plane of the planets' orbit.

The dates at which the four comets were in aphelion were found to agree fairly with the dates at which a planet whose period is 1006 years, revolving in a circular orbit, might have been in these four positions. Thus an estimate was made of the actual longitude of the unknown planet in its orbit.

The first step undertaken now has been to compute from every set of elliptic elements of all the comets in the Catalogue of Galle the corresponding aphelion distances, so as to find corroborative evidence.

Some of the comets have very wide ranges in the aphelion distances assigned by different computers of elements. There are only 17 comets in which the range of aphelion distances given by

any computers includes the distances entitling them to be included in this investigation, viz. between 85 and 135 Earth's distances.

Out of these 17 comets a great many deserved but little attention, owing to obvious doubt as to the value of the excentricity. Six comets, however, out of this class are found to lie on or close to the plane of the orbit suspected in 1880. This comes from the addition, to the four already used, of comets 1855 I. and 1882 II. Curiously enough, all the aphelion distances computed for Comet 1880 I. are very small. This is due to uncertainty, owing to the very small perihelion distance combined with the desire of computers to identify this comet with comet 1843 I. Otherwise, as shown in § 2 of this paper, Comet 1880 I. should be added to our list; also comet 1556,—thus raising the number of comets whose aphelia lie on or close to the plane chosen to eight. Four of these, however, refer to the same position and the same date.

The comet 1843 I. was one of those used in 1880. The other three which were then used, as they now are to be used, are 1840 IV., 1855 II., and 1861 I.

Concerning comet 1840 IV., out of eight sets of elements given by Galle three are elliptic, giving aphelion distances 97, 97, and 101. Of these, two are by Goetze. The third of these, the result of a laborious research, is by Schulze.

Concerning comet 1861 I., nine orbits are given by Galle. Three are elliptical—one by Pape, two by Oppolzer—giving aphelion distances 300, 110, 110. Oppolzer's final result gives a period of 415·430 years. This comet approaches the Earth's orbit very nearly (about 0·0022), but, as I explained in 1880, it certainly was seen at three previous revolutions, in 1444, 1032, and 617 I. In each of these returns the Earth's position in its orbit was far away from the comet, and the orbit could not be disturbed. The proofs of identity are as follows.

Comet 1861 I. shone in the beginning of May as a large nebula with a small nucleus and a tail only 3° long. Its greatest brightness was equal to a star of the 2nd. or 3rd. magnitude. I have computed from its orbit that if the Earth had been in the position it occupies in July the comet would have passed a little to the east of β Leonis, going towards α Virginis.

Now, comet A.D. 1444 is thus described by Biot: "On August 6 a comet 10° long was seen to the east of β Leonis. It became longer day by day till August 15, when it entered the sidereal division of α Virginis and disappeared."

Comet A.D. 1032 is thus described by Biot: "On July 15 an extraordinary star appeared in the N.E. It approached β Leonis and threw out a tail."

Comet A.D. 617 I. is thus described by Ma-tusan-lin: "In July a comet, with a tail 3° or 4° long, was seen near β Leonis; after some days it disappeared."

All three comets agree with the dates calculated from Oppolzer's orbit. All were seen about July in the direction to be expected from Oppolzer's orbit. All lasted visible to the naked eye only for

a short time. In two cases the length of tail is given, and was only 3° to 10° long, as in 1861.

I think we may safely put the aphelion date when the planet was at the same place as being A.D. 409, certainly not later.

Concerning comets 1855 I., 1855 II., no remark is required except that there is nothing to indicate any previous appearance of either.

To comet 1855 I., Tiele has ascribed two elliptic orbits, aphelion distances 206 and 124; periods 1058·6 and 520·12 years. Thus the date of aphelion is a little uncertain.

To comet 1855 II., Donati gave an elliptic orbit, aphelion distance 124, period 493 years, subject to some uncertainty.

The following elements of orbits are adopted in this investigation :—

Computer.	Perihelion Passage.	ω.	☊.	i.	Log. q.	e.
		° ′ ″	° ′ ″	° ′ ″		
Schultz, Steinheil	1840, Nov. 13, 67060	133 36 1	248 55 48	57 58 6	0·1705856	0·9711151
Tiele	1855, Feb. 5, 05384	323 5 59	189 43 33	128 35 41	0·3411427	0·965185
Donati	1855, May 30, 20781	22 39 5	260 15 7	156 52 52	9 7542137	0·9909006
Oppolzer	1861, June 3, 39641	213 26 19	29 55 42	79 45 31	9·9641181	0·98346314

[Mean Equinox, 1840·0; 1855·0; 1855·0; 1861·0.]

From these the longitudes and latitudes of aphelion are deduced. Those of the other comets are grouped together, using the mean values already determined. The aphelion distances computed by different calculators are also given for each comet.

Comet.	Aphelion Distances.	Aphelion. Longitude.	Aphelion. Latitude.
		° ′	° ′
1840 IV.,	97, 97, 101	220 56	−37 53
1855 I.,	206, 124	35 36	+27 59
1855 II.,	124	60 1	− 8 42
1861 I.,	300, 110, 110	37 18	+32 50
1843 I.,	7, 69, 16, 63, 21, 22, 173, 131		
1880 I.,			
1882 II..	83, 23, 150 to 200 (18 values), 510, 247, 261, 231	101 21	−35 21
1556.	87·52		

[All these longitudes are reduced for precession to the mean equinox 1908·0.

All of these aphelion positions lie almost on one plane passing through the Sun, the two comets of 1855 showing a slight divergence. The plane was necessarily chosen to pass through the mean aphelion position of the group of three comets. It differs little from the plane chosen in 1880. The longitude of the ascending node is 247° 34′, and the inclination is 52° 0′ 30″.

In the following table the longitude is measured from the first point of Aries along the ecliptic to the ascending node, and thence along the supposed planet's orbit, and the latitude is the distance from the assumed plane of the orbit.

Comet.	Dates of Aphelia.	Orbital Longitude.	Orbital Latitude.
		° ′	° ′
1840 IV.,	A.D. 1659, 1287, 915 (Schulze)	196 6	+ 0 13
1855 I.,	A.D. 1575 (Tiele)	40 17	− 4 34
1855 II.,	A.D. 1609 (Donati)	69 53	− 11 18
1861 I.,	A.D. 1654, 1239, 824, 409 (Oppolzer)	24 6	0 0
1843 I., 1880 I., 1882 II. 1556	A.D. 1702	114 57	0 0

It might be thought sufficient to assume a circular orbit for the planet of a radius about 100. But the transformation of the orbit of comet 1556 into three makes it nearly certain that in 1702 the planet was close to the comet, at a distance 87·52. If the mean distance is to be maintained at about 100 the orbit is excentric, and the orbital longitude 114° 57′ should be taken as the most probable longitude of perihelion, and 87·52 as the most probable perihelion distance. It is only by trial and error that the mean distance can be determined.

A cursory examination shows that, as in the paper of 1880, the fundamental feature of a solution lies in assuming that comet 1861 I. was affected by the planet at the fourth aphelion passage, counted backwards from now, in A.D. 409. The date of that aphelion passage can be fixed with certainty, as the comet's four returns have been recorded, and therefore its period is known.

This fixes the mean distance and excentricity of the orbit of the hypothetical planet.

☊.	*i*.	*e*.	*π*.	Mean Distance.	Date of Perihelion Passage.
° ′	° ′ ″		° ′		
247 34	52 0 30	0·1665	114 57	105·1	A.D. 1702

The period of revolution is 1076 years.

The next feature, as in 1880, is that comet 1840 IV. must have been affected by the planet at its third aphelion passage counted backwards from now, about the 9th or 10th century. The impossibility of verifying previous appearances of this comet renders its period dependent entirely on the three sets of calculated elliptic elements which give aphelion distances 97, 97, and 101 Earth's distances. A mean value among these gives the date of aphelion A.D. 821, fitting in exactly with elements assigned to the planet, while the planet's radius vector in that longitude would be 99·88.

Comets 1855 I. and 1855 II. must have been affected at their last aphelion passage. Donati gave to comet 1855 II. an aphelion

distance 124. I find that by assuming an aphelion distance 125·75 the comet and planet were both in the longitude of the comet's aphelion in A.D. 1608.

For comet 1855 I. Tiele's two elliptic orbits give aphelion distances 206 and 124. I find that this must be changed to 147·27 to bring the comet to its aphelion at the date A.D. 1532, when the planet reaches the same longitude.

Considering that the assumption made as to perihelion distance and longitude of perihelion of the planet's orbit is only the most probable, it will be recognised that these results go far in support of the hypothesis.

These results are shown in tabular form as follows :—

Comet.	Aphelion. Long. (Orbital.)	Aphelion. Lat.	Aphelion Distance calculated.	Aphelion Distance assumed.	Date Aphelion.	Date for Planet in same Long.	Rad. Vect. of Planet.
	° ′	° ′					
1556, 1843 I., 1880 I., 1882 II.	114 57	0 0	87,52	87·52	A.D. 1702	A.D. 1702	87·52
1861 I.,	24 6	0 0	110,36	110·36	409	409	102·7
1840 IV.,	196 6	+ 0 13	97; 97; 101	99·70	821	821	99·88
1855 I.,	40 17	− 4 34	206; 124	147·27	1532	1532	
1855 II.,	69 53	− 11 18	124	125·75	1604	1604	

It is worth noting that the aphelion distance assumed for comet 1840 IV. is 99·70; the values from computed orbits being 97, 97 and 101; while the radius vector of the planet at that longitude is 99·88, the orbit having been computed without using this comet. This remarkable agreement makes it nearly certain that the perihelion distance of the planet and its longitude of perihelion, which were chosen as probable, are not far wrong.

It only remains now to fix the present position of the planet. Taking A.D. 1702 as the date when the planet was in longitude 114° 57′, the planet's longitude in its orbit in 1908 is 201° 57′; and its position with respect to the ecliptic is A.D. 1908 longitude 215° 31′; S. latitude 33° 53′; A.D. 1914 longitude 217° 21′; S. latitude 32° 15′.

When searching for the planet it must be remembered that probably the orbit is subject to less uncertainty than the epoch, and the search should be extended forward and backwards on the line indicated by the above positions.

Such a search cannot be prosecuted except at a southern observatory.

7. Perturbations of Neptune's longitude. It ought to be mentioned here that in 1906 the writer computed roughly the perturbations that might be expected on Neptune's longitude and radius vector by the hypothetical planet on any assumption as to the mass of that planet, concerning which mass we can form no opinion.

These calculations were based upon the orbit of a planet assumed to be in the ecliptic, a hypothesis now abandoned. But the results have still a value as showing that up to the present date the presence of such a planet could not be distinctly indicated, but that in the next 30 or 40 years it should become very evident. This arises from the fact that Neptune has been observed since 1846 only, and in 1795 (Lalande's two observations), while its period is 165 years. Consequently it has been possible to combine the perturbed positions, by a suitable choice of excentricity and mean motion, to satisfy an apparently undisturbed orbit (as Bouvard did with observations over a part of the orbit of Uranus). But this treatment cannot be continued over a whole revolution.

In the following table, δL indicates the retardations that would be produced on Neptune's longitude if the mass of the planet equals that of Jupiter. Obviously, if it equals that of Neptune, these perturbations must be divided by 20. $\delta L'$ indicates the retardations that might be produced by using an undisturbed orbit, and changing the excentricity and mean motion by certain selected amounts. The second table shows Newcomb's residuals.

Date.	δL.	δL′.	(C—O) or (δL—δL′)
	″	″	″
1795	−14·46	−16·66	+ 2·20
1846	− 0·16	− 0·14	− 0·02
1855	0·00	+ 0·09	− 0·09
1864	+ 0·16	+ 0·53	− 0·37
1873	+ 1·18	+ 1·64	− 0·46
1883	+ 3·64	+ 3·83	− 0·19
1892	+ 7·47	+ 7·37	+ 0·10
1901	+11·67	+12·35	− 0·68
1910	+14·44	+18·70	− 4·26
1919	+12·98	+26·20	−13·22

	Newcomb 4-year Groups C—O.
	″
1795	+2·05
1848	+0·27
1852	−0·26
1856	−0·07
1860	+0·52
1864	+0·37
1868	−0·12
1872	+0·30
1876	−0·20
1880	−0·32
1884	+0·36
1888	+0·30
1892	−0·25
1896	+0·28

These tables show why we could not expect to detect the presence of such a planet, by observations of Neptune to this date, unless the planet's mass was enormous.

But if the planet exists, its presence, even with moderate mass, must eventually be thus revealed.

Erratum.

In Professor Turner's paper, p. 61, first line of paragraph 2,

for loss of light to the ether
read loss of light due to the ether.